
SCIENCE STANDARD 8

*All students will gain an understanding of
the structure and behavior of matter.*

INTRODUCTION

This standard, together with *Science Standard 9*, defines the fundamental understandings of the physical sciences. Specifically, the focus of *Science Standard 8* is on matter—its properties, its states, and its structure. Because matter is readily available (as solid, liquid, or gas), students can begin exploring its nature at the earliest ages, making observations and conducting hands-on investigations. Students gain an understanding of basic chemistry through experiences that allow students to sort and classify matter and to study the behavior of matter under changing conditions. Eventually their understanding of elements, mixtures, compounds, and reactions can be seen in the context of atomic structure and the periodic table of elements.

DEVELOPMENTAL OVERVIEW

How does a young child begin to make sense of all the “stuff” that makes up the world in which we live? By carefully observing and handling objects made of different materials, students will start to identify common characteristics, such as color and texture. They begin to develop the idea of matter having properties that can be used for sorting and describing. The focus in the younger grades is clearly on describing the nature and (to a limited extent) the behavior of matter. Experimenting with melting and freezing, for example, sets the stage for an understanding of the states of matter.

By the middle grades, students will realize that many objects are, in fact, combinations of different substances. The notion of how small pieces of matter join together as mixtures or compounds can be used to introduce the concept of forming new substances with new properties. The idea of chemical vs. physical change—an elusive concept at this age—can be introduced but will not be fully understood. Likewise, any discussion of atoms, elements, and molecules should not be expected to lead to a complete understanding of atomic structure.

It is in the upper grades that the atom and its constituent parts can serve as the basis for understanding chemical properties, chemical changes, and the nature of bonding between atoms to form molecules. The periodic table of elements becomes meaningful as a more sophisticated comprehension of the nature and structure of the atom emerges. The processes involved in activity at the atomic and molecular level can be discussed in the context of the various types of chemical reactions and the conditions that influence those reactions.

On the way to the achievement of this standard, students should also come to appreciate the practical aspects of knowing what their world is made of, and also to recognize how important scientific ideas are born and developed. The history of the development of our present-day understanding of the atom provides an outstanding example of the emergence and growth of scientific knowledge.

Descriptive Statement

Exploring the nature of matter and energy is essential to an understanding of the physical universe. This standard leads students from their experiences with the states and properties of matter to the development of atomic models and the underlying principles of chemistry.

CUMULATIVE PROGRESS INDICATORS

By the end of Grade 4, students

1. Describe and sort objects according to the materials from which they are made and their physical properties.
2. Recognize that matter can exist as a solid, liquid, or gas, and can be transformed from one state to another by heating or cooling.
3. Investigate matter by observing materials under magnification.

Building upon knowledge and skills gained in the preceding grades, by the end of Grade 8, students

4. Identify characteristic properties of matter, and use one or more of those properties to separate a mixture of substances.
5. Show how substances can react with each other to form new substances having characteristic properties different from those of the original substances.
6. Know that all matter is made up of atoms that may join together to form molecules, and that the state of matter is determined by the arrangement and motion of the atoms or molecules.
7. Explain how atoms are rearranged when substances react, but that the total number of atoms and the total mass of the newly formed substances remains the same as that of the original substances.
8. Explain that over 100 different atoms, corresponding to over 100 different elements, have been identified and can be grouped according to their similar properties.

Building upon knowledge and skills gained in the preceding grades, by the end of Grade 12, students

9. Know that atoms consist of a nucleus surrounded by electrons, and that the arrangement of the electrons determines the chemical behavior of each element.
10. Know that the nucleus consists of protons and neutrons, and that each atom of a given element has the same number of protons but that the number of neutrons may vary.
11. Explain how atoms can form bonds to other atoms by transferring or sharing electrons.
12. Demonstrate different types of chemical reactions and the various factors affecting reaction rates.
13. Explain how the *Periodic Table of Elements* evolved and how it relates atomic structure to the physical and chemical properties of the elements.

LIST OF LEARNING ACTIVITIES FOR STANDARD 8

GRADES K-4

Indicator 1:**GRADES K-2**

Sorting Buttons
Mystery Liquids
Gases

GRADES 3-4

Floating Columns
Cabbage Juice

Indicator 2:**GRADES K-2**

Is Sawdust Wood?
Sugar Cubes and Rock Candy
Comparing Liquids
Examining a Gas

GRADES 3-4

Changes of State with Butyl Stearate
Thermometers
Rate of Evaporation

Indicator 3:**GRADES K-2**

Using Magnifiers
Salt, Sugar, and Pepper

GRADES 3-4

Magnifier Projects

GRADES 5-8

Indicator 4:

GRADES 5-6

Density of Floating Objects
Paper Chromatography
Magnetic Separation
Floating Flag
Properties of Powders

GRADES 7-8

Solubility
Melting Points/Boiling Points
Rock Properties
Thermal Conductivity
Breaking Strength

GRADE 8 ONLY

Sludge Test
Sludge—A Practical Application

Indicator 5:

GRADES 5-6

Chemical Changes
Acid-Base Reactions

GRADES 7-8

Introduction to Ionic Reactions
Types of Reactions
Composition Reactions: Oxidation of Metal
Single Replacement Reactions
Compounds of Oxygen

Indicator 6:

GRADES 5-6

Paper Clip Molecules

GRADES 7-8

Bread Box Phase Change

Indicator 7:

GRADES 5-6

[no activities]

GRADES 7-8

Introduction to Conservation of Mass
Types of Reactions, Revisited

Indicator 8:

GRADES 5-6

Introduction to the Periodic Table
Periodic Properties of Elements

GRADES 7-8

Building a Periodic Table
History of Periodic Chart

GRADES 9-12

Indicator 9:

Electron Configuration
Spectral Analysis

Indicator 10:

Isotopes

Indicator 11:

Chemical Bonds

Indicator 12:

Reaction Rates
Catalyst

Indicator 1: Describe and sort objects according to the materials from which they are made and their physical properties.

LEARNING ACTIVITIES: Grades K-2

Sorting Buttons. Students observe similarities and differences in buttons made from a wide variety of materials. They develop a scheme for sorting buttons made of wood, plastic, different-colored metals, and other materials. For example, they can organize buttons according to size or color.

Mystery Liquids. Children describe different mystery liquids (e.g., corn syrup, cooking oil, water, vinegar) by their properties. Challenge students to detect differences in color, odor, flow, and surface tension as they try to float a paper clip. Afterwards, they try to match an unknown liquid to the ones they have described.

Supporting Educational Research: *Benchmarks*, p. 76 (4B)
Related Workplace Readiness Standards: 3.9, 3.12, 3.4, 4.2

Cases. Students fill a plastic bag with air and contrast the properties of the air-filled bag with the properties of a bag filled with solid objects. If weight is mentioned as a big difference between the two bags, use a plastic bag filled with Styrofoam™ pieces to show that solid things can also be light.

- Using a hand pump, gently blow air at the students' hands (so they feel air move) and at different objects in the classroom. The students can use this pump to fill up a balloon. Then fill a balloon with helium, and ask what will happen if the air balloon and helium balloon are released at the same time. Students predict and then verify or modify their ideas.
- Obtain some big syringes (without needles) and tubing that will fit the ends of the syringes. Provide each pair of students with two syringes and one piece of tubing. After the students connect the two syringes with tubing, instruct them to push on the plungers. They will discover that the air in one syringe can move things in the other. Challenge them to observe as many things as possible about the air inside.
- Next, students put water into one of the syringes. They will soon discover that the water can be moved from one syringe to another. Ask them to describe the similarities and differences between the air movement and the water movement.

Related Science Standards: 2, 4
Related Workplace Readiness Standard: 3

LEARNING ACTIVITIES: Grades 3-4

Floating Columns. In this activity, students use floating columns to sort objects by their densities. Students pour liquids of varying densities (e.g., strong cold coffee, alcohol, glycerine, corn syrup) on top of each other in a graduated cylinder. Give students a collection of small objects that float at different levels. They carefully drop these objects one at a time into the column and observe each object's position after it settles in one of the liquid layers. In this way, they observe a relative density for the objects.

Supporting Educational Research: *Benchmarks*, p. 76 (4B)

Related Science Standard: 2

Related Workplace Readiness Standards: 3.9, 3.12, 5.5, 5.6

Cabbage Juice. Provide students with red cabbage juice and permit them to mix it with a variety of nontoxic household products such as alcohol, vinegar, lemon juice, dissolved antacids, baking soda, and salt water. Challenge students to put the liquids into categories relative to the color they produced when mixed with the red cabbage juice.

This activity presents a good opportunity to teach eye safety in lab.

Related Science Standards: 2-4, 7

Related Workplace Readiness Standards: 3.7-3.9, 4.2

Indicator 2: Recognize that matter can exist as a solid, liquid, or gas and can be transformed from one state to another.

LEARNING ACTIVITIES: Grades K-2

Is Sawdust Wood? Students examine pieces of different types of wood (e.g., pine, oak, walnut). Using sandpaper, they change the shape of each piece of wood and make individual piles of sawdust. Ask the students questions such as

- Are the different piles of sawdust made from the wood you sanded?
- What is your evidence?

Next, students use magnifiers to examine shavings (not the sawdust) of the original woods all mixed together. (Prepare these shavings before class begins.) The students compare and contrast the shavings with the woods with respect to the following:

- color
- smell
- hardness

Ask the students how many different woods they think are present in the mixture. Challenge them to separate the shavings and then match the shavings to the original wood pieces. Afterwards, discuss the evidence for the matches. Help students decide if the sawdust and wood shavings were once part of each type of wood.

At some point, a discussion of where wood comes from or an appropriate field trip might be beneficial.

Related Science Standards: 2, 4

Related Workplace Readiness Standards: 2.1, 2.2, 2.7, 3.9, 3.15, 4.9, 5.4, 5.6, 5.7

Sugar Cubes and Rock Candy. Using magnifiers, students compare and contrast sugar cubes and rock candy. After examining the two materials, they grind each one up separately using a mortar and pestle, if available. (Remind them to wear goggles.) It will be obvious to the students that one material is harder than the other. The students observe the ground-up substances, comparing and contrasting what they see and smell. Do the two materials have a similar appearance?

Students predict what will happen if the materials are dissolved in water. Discuss their predictions. After the materials dissolve in the water, discuss how the evidence proves or disproves their predictions.

Next, students predict what will happen if samples of both solutions are allowed to dry. Then, after the solutions dry, discuss how the evidence proves or disproves their predictions. Was the rock candy a different form of sugar?

Related Science Standards: 2, 4

Related Workplace Readiness Standards: 2.1, 2.2, 2.7, 3.9, 3.15, 4.9, 5.4, 5.6, 5.7

Comparing Liquids. Give students small samples of various liquids (e.g., liquid starch, mineral oil, corn oil, vinegar, and water) that were poured from labeled larger bottles. (Do not let them know which of the larger bottles was the source of each sample.) The students carefully pour the liquids into compartmentalized trays so no mixing can occur. To help control spillage, keep in mind the following hints:

- Use a small squeeze bottle (with a cap) for each liquid.
- Plastic ice-cube trays work well as compartmentalized trays.
- Use a larger tray under the compartmentalized tray to capture any spilled liquids.
- Have sponges handy for spills.

Establish the idea of *property*. Let students observe and record the properties of each liquid (e.g., color, clarity, smell, slipperiness). They try to determine which bottle each of their liquids came from and see how many of their samples they can correctly match.

Give the students a mystery liquid (e.g., methyl cellulose), and ask them to compare and contrast it with the other liquids. They determine which liquid seems closest to the mystery liquid, and if the mystery liquid is one of the other liquids. The students present the evidence for their decision.

Related Science Standards: 2, 4

Related Workplace Readiness Standards: 2.1, 2.2, 2.7, 3.9, 3.15, 4.9, 5.4, 5.6, 5.7

Examining a Gas. Place a few drops of rubbing alcohol on one hand of each student. Place a few drops of water on the other hand. Ask the students to observe what happens. Explain that the liquids are becoming gases. Caution students about smelling the alcohol.

Ask students how they can increase the rate at which the liquids evaporate. Try any experiments they suggest. Most students will suggest blowing on their hands or waving their hands.

Do students think that the alcohol and water have disappeared? Place some water in sealed jars and some rubbing alcohol into other sealed jars. What happens? Place water in open containers around the room. In what location does the water evaporate faster? Does the water disappear or just go someplace else?

Place some perfume on a cloth on a desk. Ask students to raise their hand when they first smell the perfume. Ask them if they noticed where the hands went up first and where they went up last. Does this indicate that the perfume (and other gases) just disappear or do they go someplace else?

Finally, set up water cycle jars. The water in the bottom may or may not appear less, but water will appear all over the inside of the jars. Ask students to observe what happens. How does the water get on the inside surfaces? They can set up experiments to prove or disprove their ideas.

Note: Rubbing alcohol will hurt if placed on a cut or scratch on a student's hand. Perfume may bother some students with allergies or asthma.

Related Science Standard: 2

Related Workplace Readiness Standard: 3

LEARNING ACTIVITIES: Grades 3-4

Changes of State with Butyl Stearate. Students brainstorm the properties of water and list them on the board. Using normal safety precautions, they experiment with butyl stearate to determine its properties and how they compare with the properties of water.

Note: Some properties of butyl stearate will be immediately obvious. Other behavior will not be so obvious, such as reaction with food coloring and with water, and how butyl stearate evaporates.

In their logs or journals, students predict the effect of cooling butyl stearate. They cool a sealable plastic bag of butyl stearate by placing it in ice water. The bag should be stapled several times above the seal. They then describe what happens as the butyl stearate changes phase and compare their predictions with their observations. Discuss what happened. Ask the students questions such as the following:

- Where is the liquid butyl stearate now that it is a solid?
- How have the properties changed?
- Is the resulting solid butyl stearate?

Next, the students use warm water to melt butyl stearate. Is the melted substance the same as the solid substance? Introduce the idea of changing phase or state, and discuss the three phases of matter. Discuss other liquids that the students know can be both solids and liquids.

Discuss alternative ways to melt a bag containing butyl stearate (e.g., students' hands are warm enough to melt butyl stearate) and ways to separate a mixture of butyl stearate and water. Caution the students not to open the bag.

Students mix small amounts of water and butyl stearate in a sealable plastic bag stapled several times above the seal. First, they predict what happens when the bags are cooled. As they cool the mixture in buckets of ice water, the butyl stearate becomes solid. After separating the two substances, discuss with the students why the separation works. Could butyl stearate be reused if it became mixed with water? Discuss recycling as a process.

Related Science Standards: 2, 4

Related Workplace Readiness Standards: 2.1, 2.2, 2.7, 3.9, 3.15, 4.9, 5.4, 5.6, 5.7

Thermometers. Using thermometers, students measure the temperature of ice and water systems (mixtures). They keep records of the water temperature as the ice melts. Discuss what is happening and how we know ice and water are two different forms of the same thing. The students will observe that the ice/water temperature remains constant as long as there is sufficient ice in the water.

Water droplets may appear on the outside of the container. At what temperature did these droplets appear? Ask students where this water came from. Discuss the evidence.

Note: Cross-connect with "Condensation," a learning activity for Science Standard 10, Indicator 3.

Related Science Standards: 2, 4

Related Workplace Readiness Standards: 2.1, 2.2, 2.7, 3.9, 3.15, 4.9, 5.4, 5.6, 5.7

Rate of Evaporation. Students carefully pour water and corn oil into separate baby bottles with calibrations on the side. After measuring the volume of each liquid, allow the mixture to evaporate over several days. Periodically record the room temperature near the bottle. After a few days, the students measure the volume of each liquid. The students can use calculators to determine the rate of evaporation.

Using charts or graphs, the students can display changes in temperature and/or volume.

Related Science Standards: 5, 10, 12

Related Workplace Readiness Standards: 3.1, 3.3, 3.9, 3.10

Indicator 3: Investigate matter by observing material.

LEARNING ACTIVITIES: Grades K-2

Using Magnifiers. Students use magnifiers to look at a variety of objects such as spices, poppy seeds, salt crystals, and cork. Some suggested magnifiers include

- a tripod magnifier (ideal for the primary grades)
- a sturdy plastic bag filled with water
- water in jars of various sizes
- magnifying boxes

Magnifying boxes are especially useful for examining things that need to be contained, such as soil samples (to avoid spills) or insects that may be harmful to students or harmed by students. (Remember to release a living insect after a short time.)

Salt, Sugar, and Pepper. Students examine salt, sugar, and pepper with just their eyes and then with magnifying glasses. The advantages of the lens will be immediately apparent. (Warn them that inhalation of these materials may cause sneezing.) The students record the properties of each substance in their log or journal.

Students mix small amounts of the salt, sugar, and pepper together on small trays. Their job now is to separate them by appearance. Provide spoons, plastic stirrers, and magnifiers. At some point, the students should realize that the salt has a cube shape and the sugar does not. The pepper will be easy to separate because of its color.

Next, the students place the salt, sugar, and pepper into water. They observe what happens. Ask them questions such as

- Is the salt, sugar, and pepper still in the water?
- Can you see anything with a magnifier?
- What will happen if you let the water evaporate?

After the liquid evaporates, ask questions such as

- Is the white powder that remains just salt, just pepper, just sugar—or a mixture of each? How can you tell?
- What evidence suggests that the remaining powder is or is not salt? sugar? pepper?

Related Science Standards: 1, 3

Related Workplace Readiness Standards: 2.1, 2.2, 3.9, 3.15, 4.2, 4.9, 5.1, 5.4, 5.7

LEARNING ACTIVITIES: Grades 3-4

Magnifier Projects. Using handheld microscopes or magnifiers, students examine a variety of objects to detect similarities and differences.

- *Sand and Soil*—First, students examine sand in sealable plastic bags from various places to discover if all the sands are the same. Next, they look at top soil and subsoil (also in sealable plastic bags) from the same land location. They try to detect any differences between the two soils. By placing a clear plastic metric ruler next to an object under the handheld scope or magnifier, the students can measure the size of objects.
- *Eyes*—Students carefully examine the color portion of a partner's eyes. Brown eyes and blue eyes have easily seen spots of color that vary from person to person.
- *Five-dollar bill*—An interesting related activity is to have students examine a five-dollar bill magnified to find the name of the original 13 colonies (at the top of the columns).
- *Dust and lint*—Students look for dust and lint in the room. (Since this may be a sensitive issue and a health concern, use discretion.) They describe the kind of dirt they find in corners, near the door, and on the floor. Do different kinds of dirt exist in different places, or is all dirt the same? Ask students how they would suggest capturing each form of dirt so there would be less dirt next week at the same time.

Related Science Standards: 1, 3

Related Workplace Readiness Standards: 2.1, 2.2, 3.9, 3.15, 4.2, 4.9, 5.1, 5.4, 5.7

Indicator 4: Identify characteristic properties of matter, and use one or more of those properties to separate a mixture of substances.

LEARNING ACTIVITIES: Grades 5-6

Density of Floating Objects. The density of materials is an important concept. Students investigate this concept by comparing densities. First, they compare

- objects of similar size—on opposite sides of a balance (same size, different mass)
- objects of varying sizes but similar masses—in water (some that float vs. some that sink)

Next, students make a floating object stay just at the surface by attaching paper clips or small tacks. Finally, students form equal masses of clay into several different shapes (including at least one clay boat) to see if the shape changes the density.

Related Science Standards: 1, 2, 5, 10

Related Workplace Readiness Standards: 3.3, 3.9, 3.14, 5.4, 5.7

Paper Chromatography. Students learn about the varying complexity of molecules during this activity. Paper chromatography is a simple way for students to separate the pigments in a dye such as Magic Marker™ ink, Kool-Aid®, or food coloring. Using paper towels, a solvent (water, alcohol, a mixture), a tall glass or plastic cup, and a dye solution, they separate two or more types of substances (molecules) from the mixture.

Students create a chart of the colors separated and plot the time it took for each color to climb the paper towel using different solvent solutions.

Related Science Standards: 2, 4, 5

Related Workplace Readiness Standards: 3.3, 3.9, 3.12, 5.4, 5.7

Magnetic Separation. Provide students with a variety of items, including those composed of the following materials:

- iron, steel, and other metals
- wood
- plastic
- glass

Students sort the items based on magnetic attraction, then they discuss why there are differences in the materials. Ask them how this type of sorting process is used in a junkyard.

Related Science Standards: 1, 2, 9

Related Workplace Readiness Standards: 3.9, 3.12, 5.4, 5.7

Floating Flag. Students investigate the concept of density in liquids. They float colored liquids on top of each other to produce a floating flag for holidays or special events. Use liquids such as the following:

- orange-tinted alcohol
- colorless oil
- green-colored water

Afterwards, miscibility could be a secondary discussion as students shake the liquids and the colors change.

Related Science Standard: 2

Related Workplace Readiness Standards: 3.2, 3.7, 3.8, 5.4, 5.7

Properties of Powders. Students identify a series of common, white powders found in the home (especially the kitchen) by observing/testing chemical and physical properties. Characteristic properties recorded include the following:

- color
- texture
- microscopic crystal structure
- reaction with common substances such as water, alcohol, iodine, and/or vinegar
- reaction to heat

They first test known household substances and then identify an unknown.

As an extension activity, the students can prepare water solutions of each powder and test the solutions for acidity using cabbage juice or other indicator.

Supporting Educational Research: EES Mystery Powders Lab

Related Science Standard: 2

Related Workplace Readiness Standards: 3, 4, 5

LEARNING ACTIVITIES: Grades 7-8

Solubility. Solubility is a property that can be used to identify substances. In this activity, students prepare solutions using various combinations of solids and liquids. By measuring the volume of substances used, they learn about the concept of concentration. Students also investigate insoluble or immiscible combinations, such as oil and water, or alcohol and salt.

Related Science Standards: 2, 5

Related Workplace Readiness Standards: 3.1, 3.9, 5.4, 5.7

Melting Points/Boiling Points. Using a thermometer, students determine the melting points and/or boiling points of water. They then graph temperature vs. time. The melting and boiling plateaus illustrate the heat of fusion and heat of vaporization of the liquids.

Related Science Standards: 2, 5, 9

Related Workplace Readiness Standards: 3.7, 3.9, 3.12, 5.4, 5.7

Rock Properties. Students sort a collection of rocks or minerals by color, texture, streak, cleavage, density, or Mohs' scale reading. Next, using a different property, they re-sort the same group of rocks or minerals. By sorting and re-sorting the rocks or minerals using different criteria, students learn how different properties could be used in different circumstances.

As an extension activity, students can decide which rock/mineral could be used for each of the following: buildings, roads, statues, steps, sidewalks, jewelry, and cutting devices.

Related Science Standards: 2, 10, 11

Related Workplace Readiness Standards: 3.7, 3.12, 5.4, 5.7

Thermal Conductivity. To illustrate the concept of thermal conductivity, students use several different types and/or gauges of metallic wire. Wearing safety goggles, they place one drop of wax every 5 to 8 cm on the metallic wire, then heat one end of the wire with a candle or Bunsen burner. They time the melting of each wax drop and graph distance vs. time in order to compare different metallic wire types and/or gauges.

As an extension, ask the students to decide what type of chair they would prefer sitting on during a sunny summer afternoon.

Related Science Standards: 2, 5, 9

Related Workplace Readiness Standards: 3.7, 3.8, 5.4, 5.7

Breaking Strength. Students test the strength of wire (metal, plastic, or fiber) by connecting a wire across an open space and then suspending objects from the center of the wire. Students graph the mass each wire holds.

As an extension activity, students double, braid, or combine wires to improve strength. Ask them if the strength is proportionately increased as they increase the number of strands.

Related Science Standards: 2, 5, 9

Related Workplace Readiness Standards: 3.6, 3.7, 3.13, 5.4, 5.7

LEARNING ACTIVITIES: Grade 8

Sludge Test. Give students a “sludge” containing a mixture of soluble and insoluble solids and liquids. To determine the identity of each substance, students use characteristic chemical and physical properties such as

- magnetism
- ductility
- density
- boiling point
- freezing and melting points
- solubility
- reactions to heat and known chemicals
- flame tests

They keep a log of the processes and tests used. In their report, they discuss the reasons for each step of their experimental procedure.

Sludge—A Practical Application. After students have performed the above tests, give them the following problem to solve:

“As you walk in the woods near a lake, you notice a strange-colored area in the water. Upon closer inspection, you observe that the spot is actually a streak through the lake that comes from the north. You know that in the north there is a fertilizer factory that produces sodium and potassium compounds. As a creative and curious student, you carefully bring back this sludge, which appears to be made of more than one liquid and possibly some solids. How would you find out as much as possible about each of the substances in the mixture? How would you find out if the pollution was coming from the fertilizer factory? Write the steps you would take (as simply as possible). List the specific tests you would perform and the appropriate order. Explain the reasons why you will use these tests, and describe the anticipated results.”

Supporting Educational Research: Modeled on the IPS sludge test
 Related Science Standard: 2
 Related Workplace Readiness Standards: 3, 4, 5

Indicator 5: Show how substances can react with each other to form new substances having characteristic properties different from those of the original substances.

LEARNING ACTIVITIES: Grades 5-6

Chemical Changes. Students investigate several types of chemical reactions and observe changes both in properties and in mass. (Be sure to emphasize proper personal safety to the students.) The following are among the more interesting reactions that can be observed safely at this age:

- burning paper
- rusting iron
- bleaching cloth
- removing tarnish from silver
- vinegar and baking soda
- pennies in salt water
- iron nail in Miracle-Gro
- metal with acid
- a seashell and vinegar

Students make observations before, during, and after the reactions and compare properties and masses where possible. (The mass of the reactants is easy to determine in self-locking bags.) What evidence is there that a chemical change has occurred? To stimulate class discussion, ask students about the helpfulness/benefits vs. the destructiveness of chemical reactions.

Related Science Standards: 1, 2, 10, 12

Related Workplace Readiness Standards: 3.3, 3.11, 3.14, 4.7, 5.7

Acid-Base Reactions. Students use a nontoxic acid-base indicator to help them observe acid-base reactions. They add a specific amount of the indicator to equal volumes of vinegar (an acid) and household ammonia (a base) and observe the color changes. Then the students mix the two solutions. The resulting color changes show that the properties of the compounds have changed.

As an extension activity, students can discuss acid rain and its effects on ecosystems.

Related Science Standards: 2, 5, 10, 12

Related Workplace Readiness Standards: 3.7-3.9, 5.4, 5.7

LEARNING ACTIVITIES: Grades 7-8

Introduction to Ionic Reactions. In this activity, students determine if ions are present in dilute solutions of household chemicals. They use a conductivity device to check for the presence of ions in the solutions. In this way, they determine whether ionic reactions are possible for certain combinations of chemicals.

As an extension activity, the students discuss the environmental safety of the household chemicals used.

Related Science Standards: 2, 12

Related Workplace Readiness Standards: 3.6-3.9, 3.11, 3.14, 5.4, 5.7

Types of Reactions. Students observe a variety of chemical reactions in this activity, writing down the equations of each reaction.

- They combine two solutions that form a solid when mixed together (e.g., iron II chloride and silver nitrate).
- They place calcium carbonate in a test tube, which they close with a balloon. They heat the mixture gently until it begins to react. They compare the product to the original reactants.
- They perform the electrolysis of water experiment, in which they break water into hydrogen and oxygen find the volume of the two gases convert the volume to mass using density measurements compare the characteristic properties of both gases using a flame test

Note: “Types of Reactions” can also be used for indicator 7 if students mass all the products and reactants involved in the experiments.

Related Science Standards: 2, 5

Related Workplace Readiness Standards: 2.2, 3.1-3.15, 4.1, 4.9, 5.4, 5.5, 5.7

Composition (Synthesis) Reactions: Oxidation of Metal. The oxidation of metal is an example of a composition reaction. This common reaction produces a new material that is visually different. Students investigate the oxidation of iron filings to iron oxide by exposing granular iron or iron filings to a strong oxidizing agent, such as Clorox™ bleach, and observing the formation of a new substance. This reaction yields a change in mass.

As an extension (or alternate) activity, students can observe the oxidation of zinc or the tarnishing of silver after touching the metal to a hard-boiled egg. Is there a difference in reaction caused by touching the egg white as opposed to the egg yolk?

Related Science Standards: 2, 10

Related Workplace Readiness Standards: 3.1, 3.8, 3.11, 5.4, 5.7

Single Replacement Reactions. The reaction of aluminum with a dilute solution of copper II chloride dramatically illustrates a single replacement reaction. After observing the properties of aluminum foil, water, and copper II chloride, the students mix the water and copper II chloride and record their observations. Next, they form the foil into a boat and float it in the solution. They record follow-up observations for several minutes and then again the next day. Does the evidence show a chemical reaction? The resulting phenomena should initiate a lively class discussion.

Related Science Standard: 2

Related Workplace Readiness Standards: 3.7-3.12, 5.4, 5.7

Compounds of Oxygen. Oxygen forms compounds with many elements, producing compounds with distinctly different properties. When oxygen reacts individually with magnesium, hydrogen, and carbon, the resulting compounds are a solid, a liquid, and a gas, respectively. Students research the chemical and physical properties of these new compounds.

Paper clips of different colors and shapes can be used to model the molecules of the oxygen compounds formed.

As an extension activity, students can combine other elements using the paper clips and research the properties of the resulting compounds.

Related Science Standards: 2, 12

Related Workplace Readiness Standards: 3.6-3.9, 5.4, 5.7

Indicator 6: *Know that all matter is made up of atoms that may join together to form molecules, and that the state of matter is determined by the arrangement and motion of the atoms or molecules.*

LEARNING ACTIVITIES: Grades 5-6

Paper Clip Molecules. Students use paper clips of two different shapes or sizes to assemble a molecule from its component elements. Each student is given three pairs of similar paper clips and one pair that are different and is asked to arrange these into two identical models that use all of the paper clips. After several tries students will notice that there are a number of possible arrangements but only one is correct.

Related Science Standard: 5.1, 5.2, 5.9

Related Workplace Readiness Standards: 3.7, 3.8, 3.9, 3.14

LEARNING ACTIVITIES: Grades 7-8

Bread Box Phase Change. Using a small “bread box” device, have students stand the box on its end and trace the arrangement of the breads inside of the box. Have students slowly rotate the box and trace/draw the movement of the molecules as represented by the beads. The students then vibrate the box and draw the molecules (beads) as they are in motion.

Student groups discuss the different movements they observed and relate these to solids, liquids and gaseous phases of matter. A class discussion may follow.

(*A box is approximately a 10cm x 60cm x 1 cm clear plastic box which can be sealed with 20-30 small plastic or glass beads.)

Related Science Standard: 5.1, 5.1, 5.9

Related Workplace Readiness Standards: 3.7, 3.8, 3.9, 3.14

Indicator 7: Explain how atoms are rearranged when substances react, but that the total number of atoms and the total mass of the newly formed substances remain the same as that of the original substances.

LEARNING ACTIVITIES: Grades 7-8

Introduction to Conservation of Mass. As an introduction to the law of conservation of mass, students use paper clips of different shapes to represent reacting elements in a reaction. Students then reorganize the paper clips to represent the products. For example, three hydrogen molecules (three pairs of standard paper clips) reacting with one nitrogen molecule (one pair of butterfly clips) produces two ammonia molecules (two groupings of three paper clips attached to a butterfly clip). Measuring the mass of the paper-clip reactants and products would reinforce the law of conservation of mass.

Related Science Standard: 5

Related Workplace Readiness Standards: 3.2-3.2

Types of Reactions, Revisited. Students observe a variety of chemical reactions in this activity, writing down the equations of each reaction. They measure the mass of all the reactants before and after the experiments.

- Combine two solutions that form a solid when mixed together (e.g., zinc nitrate and sodium hydroxide).
- Combine baking soda and vinegar in a sealable plastic bag. (Experiment with amounts first!)
- Pour hydrogen peroxide in a sealable plastic bag, and place the bag in the sunlight.
- Put a damp nail in a sealable plastic bag, and leave the bag in the sunlight for several hours.

Related Science Standards: 2, 5

Related Workplace Readiness Standards: 2.2, 3.1-3.15, 4.1, 4.9, 5.4, 5.5, 5.7

Indicator 8: *Explain that over 100 different atoms, corresponding to over 100 different elements, have been identified and can be grouped according to their similar properties.*

LEARNING ACTIVITIES: Grades 5-6

Introduction to the Periodic Table. In this activity, students create an analogy to the periodic table of the elements. Each student records pertinent information about themselves on 3-by-5-inch cards. Information might include the following:

- height
- eye color
- hair color
- birthday
- favorite hobby

The class puts together the entire chart on a bulletin board. (Alternately, these cards can be duplicated and a set given to each student group.) The entire class (or individual groups) then organize the cards into rows and columns by using two or three of the facts. The students can reorganize the cards again and again using different groupings of facts. This exercise easily leads into a class discussion of the properties of the elements and their arrangement on the periodic table of the elements.

Related Science Standards: 1, 2

Related Workplace Readiness Standards: 3.6-3.15, 4.2, 4.4, 4.5

Periodic Properties of Elements. When elements are arranged in order of increasing atomic number, they exhibit a periodic recurrence of properties. Students can document periodic trends in certain properties, such as density and solubility, of compounds that contain elements in the same group. In this activity, students measure the densities of certain elements and the solubilities of certain salts. They then describe the periodic variation of the compounds.

Related Science Standard: 2

Related Workplace Readiness Standards: 3, 4, 5

LEARNING ACTIVITIES: Grades 7-8

Building a Periodic Table. The arrangement of elements on the periodic table can be illustrated by the use of an element deck of cards. Each card includes the name and/or symbol of an element as well as several of its properties, such as

- melting point
- atomic mass
- color
- atom size
- activity ranking

Remove some of the cards from the deck. Working in small groups, the students arrange the remaining cards into columns or rows by using one or two of the properties. Groups compare their combinations, and the class constructs a master chart on a bulletin board or wall. Students then compare this master chart to either Mendeleyev's chart or the modern version. The class may then discuss "misplacements" or missing cards and debate if other information is missing or if changes need to be made.

Related Science Standards: 1-3

Related Workplace Readiness Standards: 3.6-3.13

History of Periodic Chart. Working in small groups, students research the life and discoveries of a chemist who was involved in the development of the periodic chart (1800 to present). Each group develops a visual to represent the chemist's contribution to the modern periodic chart.

Related Science Standards: 3-5

Related Workplace Readiness Standards: 3.5, 3.8-3.10, 3.14, 4.2, 4.7, 4.9-4.11

Indicator 9: *Know that atoms consist of a nucleus surrounded by electrons, and that the arrangement of the electrons determines the chemical behavior of each element.*

LEARNING ACTIVITIES: Grades 9-12

Electron Configuration. Give each student group a deck of cards that contain only the atomic number of an element and its electron configuration. Ask the groups to arrange the cards into logical groupings by using only the electron configuration. Groups compare their arrangements and work together to organize the cards into a classroom chart of element families that have similar chemical behavior.

As an extension or alternate exercise, students use the activity rankings or reactions with hydrogen and oxygen to produce a similar chart. As a follow-up activity, the students could choose an element family and test each member's reactions with a particular element or solution.

Related Science Standard: 2

Related Workplace Readiness Standards: 3.6-3.15

Spectral Analysis. Absorption and emission spectra are used to identify many elements. When elements are heated to high temperatures, they may be placed in an excited state. In this excited state, valence electrons move to higher energy levels. When the electrons return to their ground state, they may emit visible light of characteristic colors, which can be used to identify the element.

In this activity, students identify the colors of the emission spectra of some metallic ions—for example, $\text{Ca}(\text{NO}_3)_2$, $\text{Ba}(\text{NO}_3)_2$, NaNO_3 , SrNO_3 —using a burner and wood splints. After reviewing safety procedures, they place a small amount of the solid ionic compounds (about the size of a rice grain) in the tip of a wooden splint. The students place the splint at the edge of the hottest part of the flame (top of the inner blue cone). They observe the color with an unaided eye and with a spectroscope. They record the results in a table and include the name of the compound, the metal ion, and the color.

Give students an unknown. Challenge them to identify it by observing its spectrum and comparing their observations with the emission spectra table they developed earlier.

Related Science Standards: 8, 9

Related Workplace Readiness Standards: 3.6-3.9

Indicator 10: Know that the nucleus consists of protons and neutrons, and that each atom of a given element has the same number of protons but the number of neutrons may vary.

LEARNING ACTIVITIES: Grades 9-12

Isotopes. Ask students to diagram isotopes of the first ten elements. Next, students research how isotopes of an element can be separated from each other. They should research C-14, H-3, and U-238 for their properties and uses.

Students may wish to use the Internet for this activity.

Related Science Standard: 2

Related Workplace Readiness Standards: 3.8, 3.13

Indicator 11: Explain how atoms can form bonds to other atoms by transferring or sharing electrons.

LEARNING ACTIVITIES: Grades 9-12

Chemical Bonds. Using electronegativities, the students determine the type of bond formed between two elements. From this information, they draw Lewis diagrams for ionic, polar, and covalent combinations. The students construct models of molecules for polar and covalent combinations using Styrofoam™ spheres and toothpicks. They determine molecular shapes, bond angles, and polarity of each molecule.

Related Science Standards: 1-3

Related Workplace Readiness Standards: 3.1-3.15, 4.2

Indicator 12: Demonstrate different types of chemical reactions and the various factors affecting reaction rates.

LEARNING ACTIVITIES: Grades 9-12

Reaction Rates. In this activity, students determine experimentally how factors such as concentration and temperature affect reaction rate. Emphasize quantitative results. Review safety procedures.

Consider demonstrating the reaction between solution A (potassium iodate, KIO_3) and solution B (soluble starch, $\text{Na}_2\text{S}_2\text{O}_5$) so the students know what to expect. (They may recall the iodine test for starch from previous biology classes.) However, avoid any discussion concerning preconceived ideas about the effect of concentration on rate before the students experiment with different temperatures and concentrations/dilutions.

Students may use water baths for this procedures, with 40°C as the highest value assigned. Assign each group a water-bath temperature. After students collect data, they make two graphs:

- time vs. concentration
- time vs. temperature

Ask students questions such as the following:

- What does the heat do to the molecules?
- What is the concentration of solution A (KIO_3)?
- Which relationship (if any) was inverse? Which relationship (if any) was direct?
- What is the variable in each situation, and how do you control it?

Related Science Standards: 2, 4, 5, 8, 10

Related Workplace Readiness Standards: 3.1-3.15

Catalyst. Students estimate the number of bubbles produced by a small amount of hydrogen peroxide placed in a beaker. In another beaker, they add a *very small* amount of manganese dioxide to the hydrogen peroxide and repeat the count. Does the addition of manganese dioxide change the number of bubbles?

Related Science Standards: 2, 4, 5, 8, 10

Related Workplace Readiness Standards: 3.1-3.15